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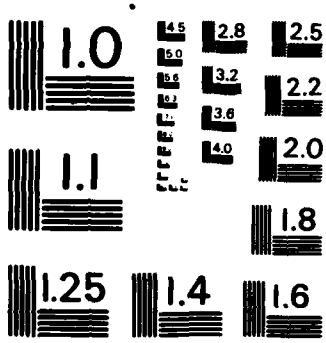

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

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Dr. Donald P. Woodward
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Code N00014
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Dear Dr. Woodward:

This letter constitutes the report of our research activities on Contract N00014-85-K-0244, entitled "Marine Cognitive Processes," for the period January 1 to September 30, 1985.

The purpose of this research is to test the limits of the cognitive capacities of California sea lions within the framework of teaching them to comprehend an artificial language composed of a trainer's arm and hand movements. These arbitrary gestural signs by a trainer are mapped on to objects in the sea lions' tank world. The signs can also be mapped on to modifiers designating place (in the case of a male sea lion, Bucky, at Matine World), size and brightness (in the case of a ten-year-old female sea lion, Rocky, and a three-year old female sea lion, Gertie, at the Long Marine Laboratory, U.C. Santa Cruz) as well as mapped on to actions taken toward the designated objects. (see Schusterman and Krieger, The Psychological Record, 1984, for a complete description of training techniques and early results with sea lions Bucky and Rocky). A second and related goal of our research is to determine the extent to which California sea lion pups "imprint" on humans and whether human attachment figures are reinforcing enough to play a significant role in controlling simple, as well as complex, learned behavior.

The major accomplishments during this past year included: (1) Teaching Gertie to perform one of three actions (fetch, tail-touch and flipper-touch) toward one of four objects (cube, bat, ring and ball) after she has been shown one of the objects (an "identity" matching to sample paradigm); (2) Co-editing a book to be published by Lawrence Erlbaum Associates, Inc., entitled "Dolphin Cognition and Behavior: A Comparative Approach." The book's publication date is Spring, 1986, and it includes contributions by Bradbury, Bullock, Eisenberg, Griffin, Herman, Hunt, Jerison, Johnson, Menzel, Morgane, Machtigall, Norris, Pepperberg, Pryor, Ridgway, Richards, Savage-Rumbaugh, Schusterman, Smith, Thomas, Wood and Wursig. The book scrutinizes a variety of approaches to the investigation of dolphin cognition and includes work on social organization and communication, feeding strategies, neuroanatomy, perception, mimicry and language comprehension; (3) Teaching Rocky and Bucky "relational fetches," that is, teaching them that a sequence of signs may mean transporting one object (gramatically speaking, the "dir-

ect object") over to another object (gramatically speaking, the "indirect object"); (4) Experiments on Rocky to find out whether adjectival or modifier signs for size and brightness can be shifted in meaning from the absolute to the relational or comparative form. If so, then does the reaction time of the sea lion tell us something about how it processes information about the relation of brightness and the relation of size, as well as the absolute values of the stimuli that instantiate the relations; (5) Testing the imprinting hypothesis with captive California sea lions. The data from studies referred to above as item (1) and (3) have not as yet been completely analyzed and will be reported next year. Experiments described in items (4) and (5) have been completed and analyzed, and brief abstracts are given below.

Transposition

In general, trainers gave Rocky a series of gestural signs referring to either standard small or large balls and a variety of black and white objects (balls, footballs, cones, etc.). The balls floated on the water surface along with other previously "named" objects. Following the sign for large or small or black or white, the trainer gave the object sign at which point Rocky broke station, searched for the targeted object, and after finding it, returned to station to receive the action sign from the trainer. Subsequently, Rocky was released from station and performed the designated action on the designated object. On 14 size transposition tests, which were given occasionally over a period of six weeks interspersed by standard trials, a much larger test ball was used in place of the standard small ball and was paired with standard large ball. Two trials were then given -- SMALL BALL + action and LARGE BALL + action randomized for sequence over the 14 tests. Long search times or latencies of judgments to the command SMALL BALL + action was hypothesized to reflect coding for the absolute characteristic of size, while accuracy of judgments was hypothesized to reflect coding about the relational property of size.

During the 14 size transposition tests in which differential reinforcement was not used, Rocky responded relationally on 13 pairs of trials ($P<.01$). On test trials when Rocky was signalled to find the small ball, her searches were very long relative to her search times on standard size trials and on test trials when she searched for the much larger ball. Table 1 summarizes the latency results.

Table 1. Rocky's latencies on the size transposition experiment.

Mean Latencies (No. of Video Frames)				
	Standard Size		Size Transposition	
	Size Gesture		Size Gesture	
	Small	Large	Small or Smaller	Large or Larger
$\bar{X}$	283	292	1108	192
SD	129	136	603	91
N	14	14	13	13

Using a slightly different procedure in which gray objects were paired with white and black objects, similar results were obtained from brightness transposition tests (see Table 2). These results show that a sea lion initially uses a specific search image and then modifies the image so as to be able to respond to the relative properties of objects. Thus, for example, when signalled SMALL BALL + action, the sea lion apparently forms a mental image of a small ball and searches the entire tank for it until it is convinced that the small ball is not present. Then, presumably, the sea lion adjusts its criterion of "small" relative to the two balls available and judges the standard large ball as smaller than the test large ball, and responds accordingly.

Table 2. Rocky's latencies on the brightness transposition experiment.*

Mean Latencies (No. of Video Frames)				
	Brightness Gesture			
	Black	White or Lighter	White	Black or Darker
$\bar{X}$	247	497	225	623
SD	95	255	150	175
N	15	15	14	14

* Rocky responded relationally on 15 of 16 black/gray pairings and on 14 of 15 white/gray pairings ($P<.01$).

Imprinting

In order to test the imprinting hypothesis, twenty-one sea lions, ranging in age from one day to about 69 months, were observed in captivity for signs of attachment to people. All tests for imprinting were videotaped and analyzed later. Animals were generally given simultaneous choices among their original surrogate mothers, their current keepers, strangers and other sea lions. Without exception, the eight sea lions, who within about 12 to 96 hours after birth were reared on a bottle by a person, showed stronger and more persistent attempts to make contact with people than thirteen "controls" (Table 3). The controls were nursed by their biological mothers for at least 21 days after birth before coming under the direct care of humans. Three of the imprinted animals were studied more closely. A yearling male and a yearling female and a three-year-old female were forced to choose between their surrogate mothers (with whom they had had no contact for at least one month) and their current keepers. All showed a strong preference for their surrogate mothers, as reflected by frequent calling, nuzzling, following and climbing-on behavior (Table 4).

Table 3. Percent of total time that hand-reared sea lions versus mother-reared "control" sea lions spent in proximity/contact with a passive person at four different marine park locations.

Marine World

Hand-Reared within 4 Days of Birth					Raised by Mother for at Least 21 Days after Birth				
Sea Lion	Sex	Testing Age (in mos)	Observation Period (seconds)	% Time	Sea Lion	Sex	Testing Age (in mos)	Observation Period (seconds)	% Time
Buckwheat	M	10	410	76	Alfalfa	M	10	410	0
					Froggy	M	10	410	0
					Elliot	M	22	410	0
					Theodore	M	22	410	0
Marineland Large Holding Pool									
Scooter	F	33	660	62	#741	F	57	660	0
Cecil	M	57	660	39	#900	F	33	660	0
					#589	M	69	660	0
					#1087	F	33	660	0
					#1138	F	57	660	0
					#724	M	69	660	0

Table 3. (cont.)

Marineland Small Holding Pool									
Xavier	M	21	540	50	#1146	?	9	540	1
Patty	F	9	540	20					
Lolita	F	21	540	5					
Sea Life Park									
Auntley	F	12	310	100	Gregg	M	12	310	2
					Huapala	F	12	310	4

Table 4. Choice of interacting among current caretaker, original caretakers, other sea lions, and being solitary by three hand-reared sea lions.

	Choices in Percent Total Time			
	Original Caretakers	Current Caretaker	Sea Lions	Solitary
Buckwheat	72	4	0	24
Scooter	60	0	10	30
Auntley	100	0	0	0

Follow-up studies have shown the durability of these attachments. A longitudinal study indicates that within one week of nursing and handling by two people, a pup forms a preferred and almost exclusive attachment to one of the individuals, who then becomes the superior facilitator of nursing and swimming behavior by the pup. The results show rather conclusively that Zalophus pups recognize surrogate mothers (primarily by their voice and odor), remember them over long periods of time and form durable social bonds with them.

Sincerely,

Ronald J. Schusterman, Ph.D.
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